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CHEMISTRY THREATENS TROPICAL PRODUCTS.*

SIXTY years ago, synthetic indigo, a dream of organic chemists, became a reality. The result of this technical triumph—the almost complete collapse of the natural industry—was the first indication of the adverse effects likely to be suffered by the producer and manufacturer of natural products when faced by competition from the technical synthetic chemist working in the same field. Since those days the pace at which new fields of activity have been opened up in the chemical industry has been extremely rapid for the synthetic chemist no longer restricts himself, as in the case of indigo, to the manufacture of products identical with the natural product. Now, when the constitution of any specific natural product is either unknown or so complex that exact imitation is impossible the difficulty is overcome by the preparation of a substitute which will serve the same purpose as—or indeed find wider application than—the natural product, although, in chemical constitution, it may only approximate to, or even completely differ from, that of the natural product. The threat of the synthetic chemist therefore covers an ever increasing range of natural raw materials.

The manufacture of substitutes for natural products, especially when the latter are both abundant and available at a considerably lower price than their synthetic counterparts, appears, at first sight, to be both uneconomic and unnecessary. To what, then, can the ever increasing progress in synthetics be ascribed? Undoubtedly the desire of certain countries to achieve self-sufficiency has done much to stimulate progress in this field but one should be careful not to ascribe all developments along this line to this one cause. The ever-increasing production of substitutes in other countries, where normal economic conditions prevail, indicates that progress in the field of synthetics is stimulated for reasons other than those connected with autarchy. Notable factors favouring the production of synthetics are as follows: the properties of artificially prepared raw materials can, as a rule, be more easily regulated than those of the natural products. Also, progressive mechanisation means, freer choice in the selection of industrial labour.

* Adapted from an article by H. N. Blommendaal, *Bulletin of the Colonial Institute of Amsterdam*, Vol. II, Nos. 2 and 3, 1939.

This factor, taken in conjunction with the independence which a country producing synthetics would achieve of those producing raw materials, would make industry more independent as to location and less bound to certain definite areas. Finally, effective protection of inventions greatly stimulates efforts to discover new materials and new methods of utilising existing substances. Under the shield of legal regulations discovering new improvements has become attractive both to the discoverer and to industry; hence research reigns supreme.

The adverse effect of continued development in the field of synthetics on the economic structure of already existing natural product industries is likely to become increasingly apparent. While, on the one hand, an ever increasing proportion of people must look to industry for a living, technical science is at the same time making rapid strides. Thus, great changes in economic relations have become a permanent threat all over the world and the keeping up of the level of the industrial sciences has become one of the most important weapons in the economic struggle. With regard to the character of future development, this is pre-determined by a certain increase of the chances of synthetic products and a corresponding decrease of raw materials as nature produces them.

Our attention has been drawn to an article by H. N. Blommendaal in which he discusses recent developments in the manufacture of substitutes for those natural products on which the economic welfare of the Dutch East Indies is largely dependent. Many of the products mentioned, however, also play an important rôle in the economic welfare of other countries, and Blommendaal's warning that the Dutch East Indies should clearly and calmly recognise the threat of the synthetic chemist is therefore just as applicable to other countries facing similar opposition from the same quarter. It is some comfort for the natural products industries to know that a period of thirty years usually elapses between an invention and its social consequences, for this means that there is always time for them to adjust matters. There is no doubt, however, that this period will decrease as research proceeds and economic organisation becomes increasingly efficient. Consequently, if existing industries wish to maintain or improve their present position they must be prepared, as soon as possible, to fight for their existence with the same weapons employed by synthetic chemists in their efforts to blaze fresh trails of economic endeavour, a struggle that will be fought out largely in the research laboratories.

Among the natural products facing competition from the technical chemist are such diverse commodities as rubber, mineral oil products, vegetable oils, fats and waxes, sugar and starch products, fibres, medicinal products, resins, essential oils, metals and ores. With regard to the manufacture of their synthetic counterparts we can only discuss here recent developments which indicate why progress in the field of synthetics is proceeding apace and offers a real threat to the producer and manufacturer of the natural products.

Though, in certain respects, not equal to natural rubber, in others synthetic rubbers surpass it considerably and offer certain technical possibilities that the natural one lacks. Buna rubber, for example, produced primarily from coal and lime, does not swell in volatile solvents, is more resistant than rubber to abrasion and shows greater resistance to the influence of oxygen, air and light. The same advantages are possessed by the American synthetic rubbers Duprene and Neoprene which so far resemble the natural product that they can be supplied as a latex similar to the milky juice of the rubber tree but with the additional advantage that the particles are comparatively smaller, making it particularly suitable for impregnation purposes.

The success of the technical chemist in this field has been so outstanding that synthetic rubber constitutes a real danger for the natural product, and one which is likely to increase as with more efficient working and larger yields the price of the synthetic product will tend to fall and find a new and an ever-increasing number of technical applications not possible with the natural variety. The extent to which this industry has grown can be gauged from the fact that in 1938 Germany produced between 24,000 and 30,000 tons of synthetic rubber whilst, during the past few years, half the rubber needed by Russia, approximately 60,000 tons, has been supplied by the synthetic product.

With mineral oil products the same general conditions obtain as in the case of rubber. In 1938 Germany produced 420,000 tons of synthetic benzine and employed the paraffin-like residues from the benzine synthesis for the preparation of fatty acids for use in the soap industry, the raw materials for which were formerly derived entirely from natural sources.

The popularity achieved by artificial silk and other synthetic fibres at the expense of the natural fibre industries is too well known to need any emphasis. A more recent competitor in this field is milk-wool (lamital) prepared from casein. This product has certain desirable properties not possessed by the natural product and its ever-increasing production does not open up much of a prospect to those lands which depend on the export of vegetable and animal raw material for the textile industry.

The production of synthetic quinine does not seem to promise any very great commercial future. More significant is the production of the two

quinine substitutes, plasmoquin and atebrin, in the sense that the world is thereby emancipated from complete dependence on the natural product and that they point the way to further research. For the present there is little to fear that such commodities as tea, coffee, cocoa, tobacco and natural fats will be dethroned by synthetic substitutes. The components to which the former owe their taste and smell, and the fats their nutritive value, form a too complicated whole to be easily replaced.

Synthetic resins, unlike the synthetic products and substitutes already discussed, are surrogates in the proper sense of the term. They do not resemble the natural resins in chemical composition, yet are entirely satisfactory as substitutes. For example bakelite, developed out of phenol and formaldehyde, is in many respects superior to ebonite or "hard rubber", and products of the synthetic resin types are superseding rubber in an entirely different field without possessing any chemical relationship with that substance whatever. Not only has artificial resin very materially affected the field which previously belonged to natural resins but its influence has been equally great outside that area. Only in a very limited industrial field is the natural product still in demand.

The question remains as to how the natural product industries are to combat the increasingly adverse effects likely to be suffered by them as progress in the field of synthetics continues. The first essential is to develop a more resistant economic structure by increasing the number of products concerned by cultivating new kinds of commercial crops or by opening up new territories, and further to strengthen the economic structure by creating an opportunity for the development of an agricultural and cattle farming middle class which should, if possible, produce commodities that at present have to be imported. Besides this complex of factors, the object of which is the improvement and stabilisation of economic welfare, measures should be taken to maintain intact all that has been acquired by so much trouble and effort. Research must be continued on the widest possible basis with a view to improving the natural product, developing new outlets by devising other forms in which to put the product on the market and to discovering new products, or bringing out hitherto unknown by-products, which promise fresh possibilities and have properties attractive to the consumer.

Research developed along these lines would be of great value if it were to lead to important results of a kind which will make the manufacturing world interested in joining forces with the plantation industry. So far this has not been achieved but it is the obvious way to hold the market—or even perhaps to increase the demand for the natural product—in the face of the advance made by synthetic substitutes.

H. F. B.

A WORLD SURVEY OF SOIL EROSION.

THE RAPE OF THE EARTH.

A World Survey of Soil Erosion. By G. V. Jacks and R. O. Whyte. London, *Faber and Faber Ltd.*, 1939. pp. 301 and Index, with 47 photographic reproductions. *Price* 21*s.*

In the opening chapter of this book, Mr. G. V. Jacks, the Deputy Director of the Imperial Bureau of Soil Science at the Rothamsted Agricultural Experimental Station, England, gives a very readable account of the modern aspects of soil erosion, in which he particularly stresses the broad economic relationships of the problems of land maintenance. "As the result solely of human mismanagement, the soils upon which men have attempted to found new civilizations are disappearing, washed away by water and blown away by wind . . . Already . . . nearly a million square miles of new desert have been formed, and a far larger area is approaching desert conditions". Despite the invention of efficient agricultural implements, the introduction of better varieties of crops, and the increased use of manures, the average output of the land per unit area taken the world over, is rapidly diminishing; this is mainly attributed to the ravages of soil erosion, which "is altering the course of world history more radically than any war or revolution". Nevertheless, soil erosion is a beneficient process without which the world would long ago have died, being Nature's way of "discarding its old worn-out skin and renewing its living sheath of soil from the dead rock beneath". In Nature, it takes place slowly, so that equilibrium is always maintained between soil removal and soil formation under particular conditions of climate. It is the *great acceleration of erosion through human mismanagement that has changed the process into "one of the most vicious and destructive forces that have ever been released by man"*. Deforestation, the destruction of natural herbage by over-grazing and excessive cultivation may so hasten soil removal that fertile land, taking centuries to form, may be entirely lost within a year or even a few days.

Until recently, soil erosion was regarded merely as a local matter, but it is now recognised as "a contagious disease, spreading destruction far and wide", and affecting almost every country inhabited by civilised man. Like other contagious diseases, soil erosion is most easily checked in its early stages; when it begins to threaten an entire social structure, its control becomes very difficult, though at this advanced stage, it may have assumed such serious and spectacular proportions that eventually whole nations have been roused to exert supreme efforts to combat the menace to their economic security.

Thus, in the United States of North America, soil erosion has become a dominant factor in national life, and here the greatest attention is now being paid to a solution of its many problems.

It is a peculiar circumstance that the systematic intensive cultivation of soils, successfully evolved in Western Europe where modern civilization had its birthplace, has proved elsewhere to be unsuitable as a basis of economic development. No sooner has European civilization been established in a new country than soil erosion, the invariable destroyer of past civilizations, has set in with the usual disastrous results. The probable reason for European immunity to soil erosion lies in the fact that the system of cultivation that was evolved in Western Europe is particularly adapted to the prevailing climatic conditions; it has been the aim there always to maintain soil fertility, and, if possible, to augment it, since the profits gained usually vary in direct proportion to the amount of labour put into the land. In other regions, notably the New World, circumstances have been entirely different; profits have been made mainly by exploiting virgin soils, notably prairie grasslands. Such treatment rapidly exhausts even the most fertile soils, which soon become eroded beyond repair, a result attributable to the "general maladjustment of land-utilization practices to the natural environment", since man has not yet proved himself capable of modifying European agricultural systems to suit the new climatic and economic conditions.

Loss of soil fertility is generally accompanied by loss in soil stability, caused primarily by the removal of protective natural vegetation. This deterioration in physical properties is the invariable precursor of erosion, and is manifest chiefly in a reduction of water-holding capacity favouring run-off rather than downward percolation and storage of rain-water. The deterioration is progressive, and soil erosion in consequence becomes more and more devastating until finally deep gullies dissect the once fertile fields and recurrent floods overflow the country. "The consequences of erosion by water may be summed up as the localized reduction of productive capacity due to direct losses of soil and of soil moisture, and the general disorganization of whole regions resulting from the cumulative dislocation of the natural water regime".

Wind erosion, though less widespread, differs but little from water erosion in its ultimate effects, and, like it, "upsets the equilibrium existing between "the life and the climate of a region". Together they have "made a knowledge of the underlying principle of human ecology one of the most urgent needs of mankind"; . . . "unprecedented land wastage . . . has set us, with our vast powers, a task that can profitably occupy the surplus human energy released . . . by the advance of science". "New outlooks, new aims and new knowledge will be required before the earth is again fit to rear . . . another civilization".

These few quotations from the introductory chapter amply indicate the outlook of the authors of this long-needed book. The chapters immediately following are devoted to the presentation of facts concerning different geographical regions that serve as illustrations to the general theme. In Chapters II to V, Europe and the Mediterranean Region, North and South America, Africa, Australia and New Zealand are considered in detail by Mr. R. O. Whyte, Deputy Director, Imperial Bureau of Pastures and Forage Crops, Welsh Plant Breeding Station, Aberystwyth, while India, China and Japan are dealt with by Mr. Jacks in Chapter VI. The chapter following (Chapter VII), by Mr. Jacks, discusses the influence of soil on erosion, and attempts to define such terms as "erodibility" and "soil structure". It is here pointed out that "the more favourable the natural external conditions (climate, slope, vegetation) are to erosion the more erosion-resistant the soil itself will become", an axiom which is well illustrated by the characteristic occurrence in the wet tropics of non-plastic, crumb-structured red earths which are known to be little affected by erosion.

The principles of soil conservation are next considered briefly (Chapter VIII, G. V. Jacks), with special reference to the now well-known methods of terracing, contour-forming, strip cropping, and damming for flood control in river valleys. The reclamation of gullies and the value of grass and of trees in soil conservation schemes are discussed in four more chapters, and dunes and deserts form the topic of Chapter XIII, all by Mr. Whyte, while some special aspects of conservation (flood control, Chapter XIV; road construction, Chapter XV; and wild-life preservation, Chapter XVI) are next considered by the same author.

The social consequences of unchecked soil erosion must necessarily be profound, since they arise from the maladjustment of agricultural communities to their environments. Maintenance and restoration of land fertility often involve an alteration of the conditions of land tenure. Two main sociological problems are outlined and discussed by Mr. Jacks (Chapter XVIII) in this connection; the first concerns semi-arid grasslands; the second problem, and the more difficult one, concerns the tropics, exemplified particularly by East Africa. In the first example, people of European stock who occupied *semi-arid grasslands* easily accommodated themselves to their environment and usually assimilated the native races. Their struggles and progress in Russia and in North America are related in Chapter XIX, where the varying degrees of economic success of different political systems (capitalism, collectivism, socialism) are fully described. In the second example, Europeans who colonized *tropical Africa* exercised little caution, believing that the luxuriant vegetation, which is so characteristic of most parts of the tropics, indicated potentially rich soil that could be directly exploited without fear of deterioration.

The fallacy of this assumption has been increasingly recognised in recent years, for the rapid onset of soil erosion has made the European settlers and administrations fully alive to the impending disaster. Moreover, the colonists have not been able to assimilate the native populations, which subsequently became segregated in reserves where they now practice a mixture of traditional shifting cultivation and modern agriculture highly conducive to soil erosion. The development and ecological results of this relationship in tropical Africa, are clearly described by Mr. Jacks in Chapter XX, comprising one of the most illuminating sections of the book. "Only exceptionally is the white man or the black man the dominant species in a tropical environment . . . (In Africa), . . . shifting cultivation . . . was the only system under which (native) races could safely cultivate the tropical forest, and nomadism the only system under which the grassland could be safely pastured . . . To-day, shifting cultivation, the sign of man's subordination to the vegetation, has become a principal cause of soil exhaustion and erosion in Africa, due to the shortening of the soil's resting period necessitated by increasing populations and the general tendency toward a more settled mode of life since European occupation . . . The white man's burden in the future will be to come to terms with the soil and plant world, and it promises to be a heavier burden than coming to terms with the natives". "It seems as though mastery over tropical soils must be secured with the help of the ecologist rather than of the engineer . . . the crying need . . . is for more biological science". "Human dominance has its allotted period in the biological succession of a region, and we do not know enough about ecology . . . to be able to skip the intermediate natural stages between dominance by forest or savannah and dominance by man". . . . "We have to learn not only the appropriate agricultural systems and operations, but also what type of society—tribal, feudal, despotic, democratic or otherwise—can co-exist on the soil during its transition from a plant-dominated to a man-dominated type".

One solution of the African problem is segregation, by means of which native and European agriculture may each develop along distinct lines, but the need for soil conservation promises to be the factor which may decide whether this will be a successful solution, for erosion control requires unified treatment and co-ordinated land-utilization practices within each natural region. It is clear that the success of any scheme for permanent soil conservation in East Africa will depend on adjustments in the system of land tenure. Thus, the communal or tribal system fails where land is limited in extent, because soil exploitation soon results in erosion, but individual land ownership is not much better, since the greater the number of properties there are, "the more difficult it is to secure adequate co-operation between the landholders". "A system of land tenure analogous to mediaeval feudalism might well develop as a way out of the impasse created by soil erosion and the conflicting demands of the indigenous and exotic races on the land". The authors suggest, therefore, that "some system which will leave the responsibility for organising and the power to enforce soil conservation in the hands of the few, while the many do the work", may well be the future basis of land tenure in tropical Africa under European influence.

The political and social consequences of soil erosion in South Africa, having nearly reached catastrophic imminence, are dealt with in a separate chapter (Chapter XXI) by Mr. Jacks, who comes to the conclusion that the best solution of the difficulties might be "the development of some system of land tenure whereby absolute control of all the land is vested in that class of the dominant race which shows itself capable of organizing for the perpetuation of conservative land-utilization", though it is not suggested that such a solution would be socially the most desirable.

In the concluding chapter, Mr. Jacks further discusses the significance of the paradoxical situation that has arisen in the world in which some of the most densely populated lands still have great reserves of fertility, whereas, in the new countries, rich lands have had to be abandoned to desert only a few decades after their settlement. Recovery by means of vast schemes for irrigating the semi-arid plains in Russia and North America may be feasible, and may induce a reversal of migration of populations back to the land. A dense population is the best insurance against erosion; for this reason, no great future is indicated for civilization in the tropics until the native races have reached a relatively advanced stage in social evolution.

In stressing the very important political and social consequences of land deterioration and soil erosion, the authors of this book have opened up the broader humanitarian aspects of agricultural science in world economy which no serious student of agriculture can afford to reject.

F. H.

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THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS.

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Introduction.

All zoologists hold the view that every animal species has arisen from some other species which was in existence before it by a process known as evolution. As to how this has been brought about there is still much difference of opinion, but evolution as an indubitable fact is not seriously disputed at the present time. That evolution has occurred derives support from an overwhelming body of evidence, which includes the results of classification, morphology, embryology, palaeontology and geographical distribution. The support given by geographical distribution is based on the fact that the animal populations of different parts of the world differ, even when the climates of the two regions are quite similar, and that this difference tends to increase with the inaccessibility and remoteness of one region from the other. This can best be explained on the supposition that the course of evolution has been different in the two regions owing to a different history in past geological ages.

The geographical distribution of vertebrates such as mammals, birds, reptiles, amphibians and freshwater fishes has been studied in detail, but little information exists as regards the distribution of invertebrates. Mammals and birds have proved the most useful for studies of geographical distribution due to their relatively rapid evolution with the production of new species. The animal population or fauna of each zoogeographical region includes many characteristic species, which are restricted to the region and are found in no other part of the earth. The species of animals comprising the fauna are determined by the past history of the region, as by the existence of land bridges which have in earlier ages allowed the immigration of certain animals but have disappeared before others were evolved, and by natural barriers, such as mountain ranges and deserts, which have prevented the dispersal of animals and have kept them restricted to certain areas.

The study of the geographical distribution of animals as developed by Sclater, Wallace, Heilprin and others does not take into account the physiological and ecological factors determining distribution. Hesse refers to this as historical zoogeography, which attempts to work out the past development of distribution at the present time by studying the homologies of animal distribution, such as the restriction of certain groups to particular regions, the absence of otherwise widely distributed forms from certain areas and the presence of closely related forms in widely separated regions. In distinction to this, Hesse defines the more recently studied ecological approach as ecological zoogeography, which takes account of the analogies between animal communities living in similar habitats, considering animals with regard to their dependence on the conditions of their native regions and in their adaptations to their surroundings, without reference to the geographical location of these regions.

Zoogeographical Regions.

The division of the land surface of the earth into six great zoogeographical regions was first proposed by Sclater who based it on a study of the distribution of birds. This was accepted by Wallace who showed that these regions served admirably not only for the distribution of birds but also for that of mammals, reptiles, amphibians and freshwater fishes and even for some invertebrates. These regions comprise (1) the Palaearctic region including Europe, Africa north of the Sahara and Asia north of the Himalayas, (2) the Nearctic region including North America as far south as Central Mexico, (3) the Neotropical region including South and Central America, South Mexico and the West Indies, (4) the Ethiopian region including Africa south of the Sahara, South Arabia and Madagascar, (5) the Oriental region including Asia south of the Himalayas, Borneo, Sumatra and Java, and (6) the Australian region including Australia, New Zealand, New Guinea and the Pacific Islands.

Heilprin later suggested that the Palaearctic and Nearctic regions be united into a single Holarctic region, for Sclater's separation of these was only based on the immigration of South American birds into North America. This has now been generally accepted. Asia was connected with North America up to the middle of Eocene times and only became separated with the break of the Bering land bridge. That Europe, Asia and North America comprise a single region is shown by even a superficial study of Holarctic mammals. Thus the European and American bison are extremely closely related, the American grizzly bear grades into the Russian brown bear, the American moose is virtually the Russian elk, the Canadian caribou the Scandinavian reindeer and the Canadian wapiti the Scottish stag.

Holarctic Region.

The Holarctic region is of great extent and its fauna includes a number of characteristic animals. The wild horse, ass, wolf, lynx, beaver, bears, moles, picas and shrews are peculiar to the region and are not found elsewhere. The wild horse, camel and elephant and probably man also evolved originally in this region. Deer are characteristic and many are of large size. The region was once the home of large mammals, such as the rhinoceros, hippopotamus, elephant, cave bear, sabre-toothed tiger and musk ox, but it has been almost denuded of its fauna by the ice ages of Pleistocene times. It has been suggested that arboreal gibbons, which once lived in the Holarctic forests, became terrestrial with the increasing paucity of the trees due to the encroachment of the ice-sheet, so giving rise

to ground-dwelling apes, which eventually led to the anthropoid ancestors of man. Among birds the grouse, partridge and magpies are peculiar and widespread throughout the region. Newts and salamanders are confined to the region. Fishes peculiar to the region include the sturgeons, perches and pikes. In the so-called Nearctic division there has been a great pollution of the Holarctic fauna by Neotropical animals, which have invaded the region from the south. Sclater, who based his division of the world into zoogeographical regions on bird distribution, did not realize this and so originally separated the Nearctic and Palaearctic divisions, which are now united in the Holarctic region.

Ethiopian Region.

In the Ethiopian region there exists an ancient primitive fauna which is overlain by a more recent incursive fauna which entered from the north. Primitive mammals are the insectivorous Cape golden mole (*Chrysochoris*), water-shrews and jumping shrews, the pangolin and the aard-vark (*Orycteropus*). Other members of the ancient fauna are the lemurs, chevrotains, civets and hyaenas. The primitive flightless ratite birds are represented by the ostrich. The recent incursive fauna includes the elephant, rhinoceros, hippopotamus, lion, zebra, giraffe, okapi, buffalo, wart-hog, conies, antelopes, gazelles, baboons, lemurs, monkeys, gorillas and many others. Of these the hippopotamus, zebra, giraffe, okapi, wart-hog, gorilla and many of the antelopes and lemurs are peculiar to the region. Madagascar possesses an exceptionally interesting fauna including many species of lemurs. The tenrecs and the aye-aye (*Chironomys*) are peculiar to the island. Deer, goats, sheep, moles and bears are completely absent from the region. Birds characteristic of the region are the guinea-fowl, flamingo, ibis, secretary bird, grey parrots, plantain eaters, mouse-birds, wood-hoopoes, sun-birds and weaver-birds. Hornbills are only found in this and the Oriental region. Amphibians include the tongueless toad *Xenopus*, the nearest relation of which occurs in the Neotropical region. The primitive lung-fish *Protopterus* is found in the region and other characteristic fishes include the primitive form *Polypterus*, and those belonging to the families Characinidae and Cichlidae.

Oriental Region.

The mammalian fauna of the Oriental region includes the tree-shrews, tarsiers, flying lemurs and gibbons which are peculiar to the region, and the lion, tiger, elephant, rhinoceros, tapir, antelopes, chevrotains, pangolins, civets, monkeys and orang-utans which are characteristic. There are many species of deer but no wild horses or zebras. Reptiles and amphibians are very well represented. The only birds peculiar to the region are the broad-bills, while the fowl-like or galliform birds and the sun-birds, the latter having habits very like the humming-birds of South America, are characteristic of the region.

Australian Region.

The Australian region is distinguished by a more extraordinary mammalian fauna than any other part of the world. The duck-bill platypus and spiny ant-eaters, which are egg-laying monotremes and the most primitive of all existing mammals, are entirely restricted to this region. The primitive pouched marsupials, including the kangaroos, wallabies, wombats, bandicoots, marsupial moles, phalangers, koala, Tasmanian devil and others are confined to the region, except for the opossums and the tucutucu (*Coenolestes*) which occur in South America. The higher placental mammals are almost completely absent. They are represented only by a few species of rats, which have probably invaded the region on floating driftwood, and bats, which have probably flown or been blown into the region. The birds are not so characteristic as the mammals, but forms peculiar to the region include the emu, cassowary and kiwi, which are primitive flightless ratite birds, the brush turkey, lyre-birds, lories, crested cockatoos, owl-parrots, honey-suckers and birds of paradise. Woodpeckers, falcons and many other birds are completely absent. The entire absence of newts and salamanders is worthy of note but frogs are present. The primitive lung-fish *Ceratodus* is found in the region.

Neotropical Region.

The Neotropical region is essentially a tropical area although the southern part of the South American continent lies in the south temperate zone. It is remarkable for the great extent and luxuriance of the dense tropical forests which almost cover the entire tropical portion. The Andes are of very considerable height; the western slopes have a singularly dry climate, while the high precipitation of the eastern slopes gives rise to a great number of vast rivers which flow eastwards through an extensive and well watered area. The temperate part of the region consists chiefly of pampas with a dry climate. This great region possesses a marvellously rich and varied fauna, which includes many animals peculiar to the region.

It is strikingly evident that a part of the fauna of the Neotropical region, and this applies to the mammals in particular, is of much later origin than the remainder. As in the Ethiopian region there exists an ancient primitive fauna which has been supplemented by a more recent incursive fauna which entered from the north. The primitive forms include three species of marsupials, a group which is otherwise restricted to the Australian region. These are the opossums and the very interesting tucutucu (*Coenolestes*), which is only found in a restricted part of the Andes in Ecuador and Colombia. Other representatives of the ancient fauna are the primitive edentate armadillos, ant-eaters and sloths, the hystricomorph rodents including the cavies, agoutis, capybaras, chinchillas and vicachas, and

the platyrrhine or New World monkeys which have long prehensile tails. All these animals are peculiar to the Neotropical region.

The recent incursive mammals include the llamas, peccaries, tapirs, deer, jaguars and pumas. These invaded the region from the north through Central America in comparatively recent times, geologically speaking, as their fossil remains are completely absent in the older rocks of South America which only contain those of the ancient primitive fauna. Blood-sucking or vampire-bats are typically Neotropical although they extend their range to the southern part of North America. Wild horses, sheep, oxen, antelopes, civets and many other mammals are quite unrepresented in the region. At the present day the camels are represented by two species found in the Old World and two species known as llamas found in South America. Llamas, which include the vicugna and huanaco, are nothing more nor less than mountain-living camels, and are found throughout the length of the Andes. They originally came from Asia, when the Bering land bridge was in existence and favourable climatic conditions permitted the widespread distribution of camels, as shown by the existence of numerous fossil remains in Siberia and North America. With the disappearance of the Bering land bridge in middle Eocene times and with changes in climatic and other conditions, the camels and llamas became restricted to the widely separated regions where they exist at the present time.

A very large number of birds are peculiar to the region. The more important are the rhea, which is the only representative of the primitive flightless birds in the region, the tinamou, curassow, hoatzin, horned screamers, trumpeters, toucans, manakins, jacamars, honey-creepers, ant-thrushes, mocking-birds, tyrant fly-catchers, American orioles, tanagers and humming-birds. The last five of these, although typically Neotropical birds, extend their range into North America. Among amphibians, salamanders and newts are completely absent, but numerous frogs and toads occur including the tongueless toad *Pipa*, which is peculiar to the region. Freshwater fishes peculiar to the region include the primitive lung-fish *Lepidosiren* and the electric-eels, while Characinidae and Cichlidae are only found in this and the Ethiopian region.

Wegener's Theory of Continental Drift.

Various theories have been advanced to account for the present distribution of land and water upon the surface of the earth, but that of Wegener is now generally accepted by scientists including the majority of zoologists, as it presents a solution to many problems, hitherto unexplained, on the geographical distribution of animals. Some zoologists, however, believe that Wegener's theory is not only unnecessary for the explanation of zoogeographical distribution but actually creates more difficulties than it elucidates. Wegener based his theory of the movement of the continents on data mainly afforded by geology. He puts forward the hypothesis that the existing land masses of the earth originally formed a single compact mass, which split in various directions, and the resulting blocks then drifted apart. It is generally accepted that the land masses forming the continental blocks are composed of lighter and relatively harder rocks than the underlying layers of the earth's surface, which are heavier and relatively plastic. Wegener contends that these blocks are floating upon, and partly submerged in this underlying matrix and are actually floating in different directions.

To account for the discontinuous distribution at the present time of certain animals, such as the lung-fishes, flightless birds and marsupials, fantastic assumptions have been made of the existence of former continents which have subsequently disappeared. Wegener's theory of the former contiguity of now widely separated continents gives a much more simple explanation of how this exceptional distribution has been brought about. MacBride has further made the interesting suggestion that the theory goes far to explain certain problems of animal migration, such as the periodical migration of lemmings in Scandinavia, the spawning of European eels in the Western Atlantic and the migration of the Pacific plover from the North American continent to Hawaii.

Discontinuous Distribution.

Certain groups of animals exhibit discontinuous distribution, occurring at the present time only in two or more widely separated regions of the earth, and for such animals it can be concluded that their distribution must once have been continuous. Tapirs are only found at the present day in Central and South America and in Sumatra, Java and Malaya, but in Eocene times tapirs were widely distributed and occurred even in Europe. The marsupials are found only in the Australian and Neotropical regions and must have had a common origin. The flightless birds are only represented by five forms at the present time. These are the rhea of South America, the ostrich of South Africa, the cassowary of New Guinea, the emu of Australia and the kiwi of New Zealand. Not only does structural evidence indicate that these birds must have had a common origin, but this is supported in addition by the presence of a single common species of Mallophaga or bird-lice. The lung-fishes show a similar discontinuous distribution. There exist only three genera of these fishes, *Lepidosiren* found in the Amazon of South America, *Protopterus* found in the Congo and other rivers of Central Africa and *Ceratodus* found in the rivers of Queensland. Among amphibians the two existing genera of primitive tongueless toads are only found in two widely separated regions, *Pipa* in South America and *Xenopus* in Africa. Wegener's theory of continental drift, which postulates the former contiguity of now widely separated continents, presents the most plausible explanation of discontinuous distribution.

Fauna of Islands.

Recent continental islands such as the British Isles and Borneo have few indigenous and peculiar animals and the fauna differs little from that of the continent from which they separated. The only animal peculiar to the British Isles and found nowhere else is the Scottish red grouse. Continental islands which separated from the mainland in more distant times such as Java, Madagascar, Celebes and New Zealand have many peculiar animals and have many groups of animals completely absent.

Madagascar possesses a most extraordinary fauna. Not only are there more species of lemurs than all the other mammals in the island but the number of species exceeds that of the rest of the world together. The aye-aye (*Chironomys*), a primitive lemur-like animal, and the tenrecs, primitive insectivorous animals which are especially numerous, are restricted to Madagascar. It has been suggested that Madagascar was colonised by animals on river rafts drifting from Africa and that the species peculiar to the island evolved here in isolation, but this is at most only a plausible possibility.

New Zealand has many species of indigenous freshwater fishes, reptiles and birds, almost all of which are peculiar to the islands, but there are no indigenous mammals, except for bats which are capable of flight, and only a single species of amphibian. It is separated from the continents by such great distances, and has been isolated for so long a time, that its fauna is in many ways similar to that of an oceanic island.

Oceanic islands are all of volcanic origin having been thrown up from great depths in the sea. The Azores are 900 miles from the nearest land and have no freshwater fishes and no mammals and their fauna consists almost entirely of birds, only one of which is peculiar to the islands. The Azores lie in a storm area and birds are being swept repeatedly from the mainland to add to the fauna of the islands. The canary is only found in the Azores and other nearby oceanic islands, such as the Canaries and Madeira.

The Galapagos are 700 miles from the South American mainland, and have many species of indigenous and peculiar reptiles and, of the many species of birds, there is only one which is not peculiar to the islands. In distinction to the Azores, these islands lie in the doldrums and have thus been isolated from invading animals, except those able to fly there or which have been carried there from the mainland on driftwood. Wallace was the first to realize that the Galapagos are a remarkable example of isolation leading to the evolution of new species, and when Darwin visited the islands he was no less struck by the significance of their fauna.

Hawaii is 2,000 miles from the nearest land and has no mammals but a very large number of species of birds, almost all of which are peculiar to the islands. Many of these birds show American affinities and others Australian affinities and here again the great isolation of Hawaii has led to the evolution of new species.

Fauna of Trinidad.

Trinidad is a recent continental island which separated from the South American mainland in comparatively recent times geologically speaking, and its geological structure conforms generally with that of the adjacent part of Venezuela. In common with other islands of similar origin it has few peculiar animals and its fauna differs little from that of the continent from which it separated.

Indigenous mammals include marsupials, edentates, ungulates, rodents, carnivors, bats and monkeys. The marsupials comprise four species of opossums only two of which occur commonly, the manicou and the manicou gros-yeux. The edentates are represented by two species of ant-eaters, the mataperro and the silky ant-eater or poor-me-one, and a single species of armadillo, the tatu. The ungulates consist of a single species of deer, the biche, and a single species of peccary, the quenk. A species of manatee occurs rarely in the estuaries of the larger rivers. The rodents are represented by about sixteen species, the more interesting of which are the lappe, agouti, porcupine, squirrel and pouched rat. The carnivors are poorly represented and include only four species, the ocelot, mangrove dog, high-woods dog and otter. The bat fauna is remarkable and comprises no fewer than thirty-four species. Their feeding habits are exceptionally varied and include fish-eating, insect-eating, flesh-eating, nectar-lapping and blood-lapping. The most remarkable of these bats is the vampire or blood-lapping bat (*Desmodus*), which has been shown to act as a vector of the virus causing paralytic rabies in cattle and occasionally in man. The monkeys include two species, the weeping capuchin and the red howler.

The birds are typically those of the Brazilian sub-region of the Neotropical region, the avifauna being closely related to that of the neighbouring part of Venezuela. The more interesting birds include the tinamou, scarlet ibis, jacana, guacharo, giant goatsucker, king of the woods, jacamar, toucan, parrots, manakins, ant-thrushes, wood-hewers, American orioles, tyrant fly-catchers, tanagers and humming-birds. The reptiles include a single species of caiman, two species of tortoises, the morocoy and the galape, many species of snakes of which four are poisonous, and numerous species of lizards. The poisonous snakes are the bushmaster or mapipire zanana, the fer-de-lance or mapipire balsain and the large and small coral snakes. The non-poisonous snakes include the boa constrictor or macajuel, the anaconda or huilla, the tree boa or cascabel and many others. The lizards comprise about twenty species including iguanas, geckos and legless lizards. The amphibians include many species, the tree frogs being especially numerous. The exceptionally interesting tongueless Surinam toad (*Pipa*) occurs rarely as does the paradox frog. Freshwater fishes include Characinidae with four genera of so-called sardines and Cichlidae with three genera of coscorobs. The invertebrates include many forms of exceptional interest particularly among the arthropods, the occurrence of *Peripatus* being especially noteworthy.

DEFORESTATION AND SOIL EROSION IN TRINIDAD.

Deforestation and Soil Erosion in the Foothills of the Northern Range Caused by Shifting Cultivation.

By J. C. Cater.
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1. The Foothills Region.

A recent, and perhaps somewhat superficial, survey has been carried out to determine the amount of deforestation that has taken place in the foothills of the Northern Range, since there is sufficient evidence of erosion to give some cause for alarm. The area surveyed has embraced all the land south of the main ridge of the Northern Range between Maraval on the west and Tacarigua on the east. It is true that there are erosion problems elsewhere in the Northern Range, but it was felt that the area indicated above presented by far the most difficult problems.

There is extremely little flat land in the foothills region, about 75 per cent. of the area is over 500 ft. above sea level and about 25 per cent. over 1,000 feet above sea level. Most of the slopes are very steep, some even precipitous. Roads are confined to the valley flats, but bridle tracks lead up from the roads to the ridges. The rainfall is somewhat variable, being about 70 to 80 inches per annum in the valleys and considerably more on the hilltops. South of the foothills the rainfall drops rapidly to 50 to 60 inches per annum. In normal years nearly all the rain falls during the last 7-8 months of the year, and on occasions the rain is extremely heavy. The period January to the beginning of May is usually marked by a drought, when the vegetation becomes tinder-dry.

The soils of the foothills are derived from mica and quartz schists, and from the occasional limestone masses such as are found at Laventille and Cameron. Owing to the steepness of the slopes, erosion takes place at such a speed that a proper soil profile is never developed, even under high forest. The hillside soils are very shallow, often with the parent rock only 6 inches below the surface, and where serious erosion has taken place the shallow soil is studded with boulders. Were it not for the fact that the mica schists decompose very rapidly on exposure to the elements, there is little doubt that much of the steeper hillsides, where serious erosion has followed persistent cultivation, would consist of the bare rock. The soils, particularly those derived from the quartz schists, are by no means fertile, but there are deeper and more fertile soils in the valleys between the hills.

2. The Vegetation.

The original vegetation supported by the foothills before the advent of the human race to the island, almost undoubtedly consisted of tropical evergreen rain forest, with a proportion of deciduous and semi-deciduous species, such as cedar (*Cedrela mexicana*), cypre (*Cordia alliodora*), poui (*Tabebuia serratifolia*), &c. Balata (*Mimusops balata* var. Cruegeri) was probably common, as it is still plentiful on the seaward side of the watershed. The last remnants of this forest can be seen on the upper slopes of the Santa Cruz valley near St. Ann's peak, and further east in the Tacarigua proposed Forest Reserve.

During the period of Spanish ownership of the island, the forest in the valley bottoms was cut down and replaced by cacao plantations. After the advent of the French refugees, about the time of the French Revolution of 1793, and later the arrival of English colonists, when Trinidad became part of the British Empire, more forest was cut down in the valleys and on the lower slopes and cacao was planted. A certain amount of cacao was even planted at the higher elevations, and there are to-day cacao plantations at an elevation of 2,000 feet above sea level on Morne Mal D'Estomac at the head of the Maraval Valley.

In the main, however, cacao was confined to the valleys and the lower slopes, and there was never any considerable permanent cultivation of the middle and upper slopes of the foothills. For a considerable time past a very large proportion of the slopes of the foothills have been subjected to severe shifting cultivation, which has destroyed almost all traces of the original forest vegetation. To-day the vegetation over most of the foothills consists of a very poor type of second growth containing numerous palms such as gru-gru (*Acrocomia aculeata*) and the trash-palm (*Sheelia osmantha*). The commonest trees are bloodwood (*Croton gossypifolius*), balsa (*Ochroma pyramidale*), saltfishwood (*Machaerium robinifolium*), gommier (*Tapira guianensis*), and kiskidee (*Vismia falcata*). Shrubs are numerous and frequently the whole mass of vegetation is closely tied up with vines and razor-grass. The bush becomes tinder-dry during the normal dry season and is very liable to be overrun by fires. Small patches of bracken (*Pteridium aquilinum*) can be seen on the hills to the north of Port-of-Spain, and further east, between 700 feet and 1,500 feet elevation, there are areas of savannah similar to the Piarco and Mausica Savannahs. There the dominant grasses are *Trachypogon plumosus* and *Thrasya robusta*, while a sedge, *Scleria sp.*, and a coarse grass, *Axonopus equitans*, are also found. The grasses are tufted, with eroded channels between the tufts. The dominant shrubs are *Curatella* and *Byrsonima*. The bracken patches are almost certainly the result of continuous shifting cultivation and fires which have resulted in severe sheet erosion of the originally shallow soil. It is not known if such areas can eventually revert to forest, but the process of re-establishment is likely to be very slow and probably depends very largely on the prevention of fire. At present fires occur almost every year.

FIG. 1.—*Maraval Valley.*—Photo shows steep hillsides at the head of the valley cleared for shifting cultivation.

FIG. 2.—*Maraval Valley.*—Land cleared for temporary cultivation on hills above residential district, subjecting the latter to serious flooding after heavy rain.

FIG. 3.—*Maraval Valley.*—Land recently cleared of vegetation, showing severe gully erosion commencing.

FIG. 4.—*Maracas Valley.*—Land over 1,000 ft. elevation cleared for shifting cultivation.

FIG. 5.—*Maracas Valley.*—Steep slopes cleared for shifting cultivation.

The origin of the hill savannahs is not known with certainty. They may be the result of continuous shifting cultivation and fires, but there is some historical evidence to show that they may be a natural phenomenon, since a Spanish adventurer of the 16th century has recorded that he sailed up the St. Joseph River and eventually reached a natural savannah from which he obtained an extensive view of the island. It is, of course, possible that the savannahs are the result of human activities long before the advent of the Spaniards to the island.

3. Cultivation.

The methods of cultivation of the hill slopes are wasteful and primitive in the extreme. During the dry season the bush is cut down and burnt. The law requires that fire traces at least 25 feet wide shall be cleared all round a parcel of land which is to be burnt, but adequate precautions are not always taken and frequently fire escapes from the area to be cultivated into the neighbouring bush, and large areas are damaged. No attempt is made at contour-ridging, terracing or planting in lines along the contours, and the extreme steepness of some of the slopes is no deterrent to the would-be cultivator. The fear of praedial larceny drives many cultivators to utilise land at very high elevations, in the hope that the difficulty of extracting the harvest from such situations may deter the thief, who will confine his attentions to the gardens at lower levels.

The burnt land is sown or planted when the rains break, usually during May. The land is then completely bare of vegetation and the heavy downpours play havoc with the exposed soil. Very large quantities of surface soil are removed by sheet erosion and carried down the slopes. Gullying also takes place to some extent, but does not seem to be so severe as sheet erosion. It is by no means uncommon to find stones which were originally on the surface supported, after heavy rains, on a pinnacle of soil two inches or more high. The eroded soil gradually makes its way down the slopes during successive periods of rain and is eventually deposited on the low-lying lands or carried out to sea. After rain has fallen in the foothills, the rivers which drain them are loaded to capacity with silt and change within the hour from gentle streams to roaring torrents which overflow their banks and floods the flat land in the Caroni plain, destroying small houses and rendering roads impassable.

The crops commonly planted are sweet corn, tomatoes, carrots, chives, yams, &c. They have little effect in decreasing the speed of surface run-off of water which is not absorbed by the soil. Usually the crop is reaped within six months of planting. A second and sometimes third crop is grown on some land, but often the land is abandoned after one crop, when erosion and the needs of the crop have exhausted the fertility of the soil. The abandoned land gradually reverts to bush through the invasion of plants from neighbouring areas of second growth and the coppicing of stools not destroyed by fire. After the land has rested for a number of years, usually from three to seven, a certain amount of fertility is built up under the cover of the second growth, and it is again cleared for cultivation.

4. Ownership of Land in the Foothills.

Unfortunately the reservation of land as Forest Reserves did not commence until the beginning of the twentieth century, when nearly all the land in the western foothills had been alienated. To-day there are under 2,000 acres of land owned by the Crown in the foothills between Maraval in the west and Tacarigua in the east. The rest of the land, some 28,000 acres of which lie above the 500 feet contour, is divided between small and large proprietors in the rough proportion of 2 : 1. The renting of lands for shifting cultivation is quite an important item in the revenue of many of the estates, rentals varying from $2.00 per acre to as high as $8.00 per acre.

5. Suggested Methods of Control.

Shifting cultivation and its attendant evils have now reached serious proportions in the Northern Range foothills, and it is highly desirable that some form of control should be introduced to protect the community. To decide what form the control shall take, however, is not an easy problem. Considerable quantities of food are grown on the foothills, an important matter to a community which is largely dependent on imported foodstuffs, and it is most undesirable to reduce the total land area under cultivation of locally consumable crops.

One method, and the most drastic, springs to mind at once. It is to prohibit all cultivation of the shifting type on land lying above the 300 feet contour, and allow the land to revert to forest. This would undoubtedly result in an enormous reduction in soil erosion and flooding. To compensate for the loss to cultivation of some thousands of acres of land, it will be necessary to find suitable land elsewhere. This should present no insuperable difficulty. Apart from the large areas of derelict land throughout the Colony, where, in spite of the low fertility of the soils, crops of vegetables could be raised under a system of controlled shifting cultivation, there are thousands of acres of abandoned or almost worthless cacao plantations on somewhat better soils. Such cacao produces a negligible crop, which it is not economic to harvest, and even requires a considerable expenditure of public funds in the form of a subsidy to maintain it at all. This cacao could be cut down and replaced by a mixed animal and vegetable crop husbandry which would afford a decent return to the cultivator and be of great value to the Colony.

An alternative, less drastic and probably less effective method of dealing with the problem, would be to permit cultivation of the slopes up

to a higher elevation, say the 500 feet contour, and try and educate the cultivators in measures which would reduce the rate of surface water run-off and hence erosion. Research work is required to determine what measures are most effective and economical in preventing erosion, and it is suggested that terracing, contour ridging, planting along contour strips alternating with strips left in bush or grass, and the use of a grass-sod of species having a prostrate form through which the crop is planted in shallow holes should, among other methods, form the subject of experiment. No cultivation of temporary crops should be permitted above the 500 feet contour, but the cultivation of orchard crops such as tonka beans, limes, &c., might be allowed between the 500 feet and the 800 feet contour, provided the soil was protected by an adequate grass cover and drains were properly aligned and constructed. Above the 800 feet contour no cultivation of any crop other than cocoa should be permitted, and as much of the land as possible should be allowed to revert to forest. The process of reversion to forest could be accelerated by tending operations such as vine-cutting, removal of excess coppice shoots, &c. Whatever form of control of cultivation in the foothills is adopted, there is no doubt that the sooner the control begins the better for the welfare of the Colony.

Acknowledgment.

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KENYA'S PASTORAL NEEDS.

In 1929, an agricultural commission under Sir Daniel Hall reported on the grave condition to which certain native reserves in Kenya had been reduced as a consequence of overgrazing and soil erosion, and recommended an immediate reduction in livestock and an increase in agriculture as means of countering a serious and growing menace to the existence of the country. In 1931, Sir Frank Stockdale reported than an increase in agriculture and consequent reduction of area available for grazing were accentuating the dangers of erosion. In 1933, the Kenya Land Commission recommended an extension of the cropped area, using dry-farming methods, in order to increase production in densely populated reserves. In 1936, Sir Alan Pim's report on Kenya directed attention to the danger of extending the cultivated area without suitable precautions being taken to maintain fertility, and to the absence of any definite policy with regard to soil erosion. In 1937, both Sir Frank Stockdale and the recently appointed soil conservation officer (Mr. C. Maher) expressed the view that the overworked land needed a complete and prolonged rest without which much of it was irretrievably doomed. They further recommended the development and intensification of agriculture to compensate for loss of production from 'rested' land.

This summary of the recommendations of some of the consulting 'physicians' who have attended Kenya in the last ten years of its decline is given (in more detail) in Dr. Pole-Evans' account of a visit to the Colony last year.* It will be noticed that all the other physicians recognized that the worst affected parts needed rest, but proposed to maintain productive capacity by throwing an additional burden on to other parts, that is, by extending agriculture. That the productive capacity of the native reserves must be maintained at a certain minimum in the immediate interests of the inhabitants is the burden of these physicians' arguments. Dr. Pole-Evans is more forth-right in his recommendations. He is a South African ecologist who lacks the bedside manner of the official reporter or commissioner. He considers that the situation is so grave that the complete rest which should have been given years ago is now imperative and must be given regardless of economic and political obstacles, if a greater future disaster is to be avoided. The remedy he proposes is simple on paper; it has been used time and again in history to rest exhausted land while keeping it under human control, and it has rarely failed. It consists in restoring the natural grass cover and utilizing animals in suitable numbers to keep the grass in good condition. It means a general reversion to less productive pastoral farming with greatly reduced stock in densely populated native reserves. Dr. Pole-Evans admits the value of supplementary measures of soil conservation—afforestation, terracing, strip-cropping, &c.—but they are practically useless unless the foundations of native society are grounded in pastures. The population can only support itself on a predominantly pastoral basis if administrative intelligence and action are concentrated on the problem of growing luxuriant grass on exhausted land in a semi-arid climate. The solution of that problem will demand all the resources of science backed by wise and far-sighted administration, and Dr. Pole-Evans' report is a plea that the necessary help and encouragement of the right kind be given before it is too late.

The report is depressing in the extreme, but it carries deadly conviction. One wishes that it could be read and its implications understood by every member of Parliament. We might then get the beginnings of a Colonial policy which takes account of the harsh—the very harsh—realities of Nature that will determine policy in the end.—(*Nature*, Vol. CXLIV, No. 3640, 1939, p. 255.)

G. V. J.

* Report on a visit to Kenya. By Dr. I. B. Pole-Evans. pp. 36+18 plates. (Nairobi: Government Printer, 1939.) 2*s*. 6*d*.

A SUMMARY OF EXPERIMENTAL WORK ON VARIETAL RESISTANCE OF SUGAR-CANE TO *TOMASPIS SACCHARINA* 1936-39.

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Introduction.

In 1936 the Imperial College of Tropical Agriculture, in co-operation with the Sugar-Cane Investigation Committee of Trinidad and the Central Sugar-Cane Breeding Station of Barbados, undertook a programme of research into the behaviour of varieties of cane, reared in Trinidad from fuzz, with regard to their susceptibility to damage by froghopper (*Tomaspis saccharina* Dist.), in order to secure data which would guide subsequent genetical work in the search for a 'resistant' variety.

The factors causing the variation in damage which has been noted in field surveys have been elucidated by the work of Pickles, Hardy and Turner, and the following factors, varying in importance between localities, profoundly affect the result of an attack :—

(i) The numbers of the initial population of froghoppers.
(ii) The degree of vigour of the cane.
(iii) The nutrient status of the soil.
(iv) The physical status of the soil and the degree of fluctuation in soil moisture.
(v) The varieties of cane available.

While improvements in cane agronomy have contributed to the prevention of outbreaks of 'blighting' by *Tomaspis*, damage by froghoppers remains a serious source of loss in Trinidad and the production of commercial varieties resistant to attack would be of great value to the industry. Pickles and Taylor (1) in a summary of field observations on varietal behaviour defining the ideal type, stated that it "should not be attractive to froghoppers, it should develop only slight leaf damage when froghopper populations attack it and should recover rapidly from any leaf damage which does occur." In this paper they state that the variety Co. 213 is less susceptible to blighting than the majority of canes grown in Trinidad (in 1934), while varieties such as B. 417, BH. 10(12) are definitely susceptible to attack. The observed difference between Co. 213 and BH. 10(12) was confirmed in a controlled experiment (2), and the view was expressed that the greatest degree of resistance might be found in canes with the greatest proportion of 'wild blood'. In 1936 a similar experiment was carried out by the writer in which the following varieties were compared: Uba, POJ. 213, Co. 281, Co. 213, FC. 916 and BH. 10(12). Comparison was made of the number of blight-streaks and puncture marks on the leaves, and although damage was not of noteworthy severity, it was established that Uba was significantly less punctured than BH. 10(12). As it is necessary that a commercially resistant variety should have a superiority very far above the lowest limit of statistical perceptibility, field experimentation since 1936 has been confined to observing randomised plots of the progeny of various crosses made in Barbados. In the fortuitous absence of heavy froghopper infestation from the plot-localities clear cut results have not yet been obtained. It has been possible to discern the variation between extremes maintained over two years and to record that of the varieties used; the crosses Uba × B. 6835 and Toledo × Sc. 12/4 alone have so far remained free from attack, while others, B. 3215 × BH. 10(12), POJ. 2752 × B. 3358, and B. 35185 × B. 2935 have proved to be definitely susceptible. The varieties Co. 213 and Uba, which have been shown to suffer less than BH. 10(12), have both on occasion been noted by several observers to suffer marked blighting, thus indicating that though less visited, these canes are by no means repellant.

Alternative hypotheses to account for the relative resistance of such a variety as Co. 213 offered themselves: it was possible (i) that the leaf structure itself gave partial protection by imposing greater mechanical difficulties in the way of the insect when it attempted to feed, or (ii) the cane was less attractive in taste, succulence or in odour.

Leaf Structure.

The principal morphological features of the sugar cane leaf which might be expected to have some bearing on the feeding of a hemipterous insect are (i) the thickness of the cuticle or of the epidermal cell-wall, or of both; (ii) the presence of spines; (iii) the size and distribution of the vascular strands and of the inter-stomatal cells.

A comparison was made of the thickness of the cuticle and cell wall, from upper and lower leaf surfaces, of samples of leaves of Co. 213 and BH. 10(12) collected from adjacent stools in a small randomised plot. Samples were taken in tall cane of the seventh leaf from the central whorl, and pieces were cut from the leaves half way along their length. In sectioning the cut pieces were folded fanwise, and sections were chosen at random. The sections were stained in Sudan III for not less than one hour. Each unit represents approximately 0.5μ.

		Average thickness of cuticle	S.E.	Average thickness of cell wall	S.E.	No. readings
Upper surface of leaf.	BH. 10(12)	1.926	.140	9.53	.399	33
	Co.213	1.685	.061	10.63	.407	33

A difference of cuticle means of more than .279, of cell wall means of more than 1.164 is significant.

Lower surface of leaf.	Average thickness of cuticle	S.E.	Average thickness of cell wall	S.E.	No, readings
BH. 10(12)	1.475	.076	9.700	.675	20
Co. 213	1.500	.070	9.543	.403	23

A difference of cuticle means of more than .219, or of cell wall means of more than 1.638 is significant.

The results revealed no significant difference of cuticle or cell wall in the sections examined.

It was considered that the difference in cuticular and epidermal thickness between the two varieties would be very pronounced if it were the case that one surface could impede, and usually prevent, the ingress of the maxillae and mandibles of *Tomaspis* while the other could not. Yet no significant difference was found, and no support is given to the hypothesis which postulates such a difference.

There is in addition another independent consideration bearing on this point. Occasional heavy attacks on Co. 213 have been recorded. These are measured by blight marks, each the result of a successful puncture of the leaf. Unless it be assumed either that some stands of Co. 213 have subnormally thin cuticles, or that some broods of froghopper have abnormally strong mouth parts—highly unlikely in either case—it is clear that in the field Co. 213 is left alone for reasons other than the mechanical resistance offered by its leaf.

The presence and quantity of spines* in a number of varieties was recorded, but no correlation with incidence of froghopper attack was noted, nor any association of sufficient interest to warrant further investigation in this connection. In extremely narrow-leaved varieties—not of commercial value—the spines along the edge of the vascular strands practically meet over the interstomatal rows. This might conceivably be of some protection against sucking insects, but no parallel has been discovered in the commercial varieties so far examined.

The assessment of the size and distribution of the cells as seen in surface view was at first restricted to a count of the number of stomata per unit area. This was arrived at by averaging the results per variety obtained from uniform samples of leaves selected in a definite manner. It soon became obvious that both number of stomata and size of individual stomata had no apparent relation with the problem under discussion. In an examination of scores of portions of leaf surface it was noted that the cell-pattern varied considerably: in some the cells were very narrow, or were numerous in the vascular bundles, while perhaps only two or three rows bearing stomata lay between them; in others the cells were relatively broader, the vascular bundles contained fewer components, and the rows with stomata in them reached up to five or seven. It was decided to express the patterns of the upper leaf-surface as an index by noting the number of cells in 50 pairs of vascular and intervascular rows of the upper leaf surface, and reducing them to one figure by the formula $\frac{x}{y} \times 10$, where x=total number of intervascular rows in the 50 sets and y=total number of vascular rows.* It was found that the patterns were so repetitive that the standard errors were very low, and varieties once indexed could readily be identified by their index irrespective of where the leaf was taken. A comparison of these indices revealed an interesting relationship. Uba and Co. 213 both had a low index, while BH. 10(12) and other noble canes had a definitely high index. The varieties Uba × B. 6835 and Toledo × Sc. 12/4 mentioned above have a low and B. 3215 × BH. 10(12), POJ. 2752 × B. 3358, and B. 35185 × B. 2935 a high index. Moreover, the arrangement of canes according to index appears so far to conform reasonably closely with an arrangement according to their observed drought resisting propensities, and it is possible that the index is an expression of the difference in xerophytic habit. It is possible (i) that a plant with a high proportion of rows bearing stomata, having beneath them leaf mesophyll, might be more succulent than any other type; (ii) that in such plants the daily water losses are higher than in varieties with lower index, and that the moister microclimate in the vicinity of such cane is attractive to the froghopper; (iii) that a greater quantity of diffusing moisture from the leaves is accompanied by a stronger aroma of sugar cane than in other varieties; (iv) that the sap and the aroma of such varieties is most attractive to froghoppers, and that the high index is correlated with the presence of such sap either fortuitously or as part of a definite combination of varietal characters. All the above possibilities refer to the second hypothesis, which postulates that 'resistant' cane is less attractive in taste, succulence, or odour. In this problem it is not proposed to touch upon the vexed and probably insoluble questions of gradations and intermingling of sensory perception in insects. Taste here is used only to mean the appreciation of the quality of liquid food after imbibition, olfaction or smell to mean the appreciation at a distance of the quality of substances whether liquid or solid, whether by the use of antennae, protarsi or any other organs not in direct contact with the object giving off the odour.

* Pointed siliceous outgrowths mainly distributed along the edges of the vascular strands.

* *e.g.* patterns $\overset{\frown}{11.1} \cdot \overset{\frown}{11.2} \cdot \overset{\frown}{10.2} \cdot \overset{\frown}{11.1}$ and $\overset{\frown}{5.3} \cdot \overset{\frown}{4.3} \cdot \overset{\frown}{6.4} \cdot \overset{\frown}{5.3} \cdot \overset{\frown}{7.3}$ give indices $\frac{6}{43} \times 10$ (1.395) and $\frac{16}{27} \times 10$ (5.926) respectively.

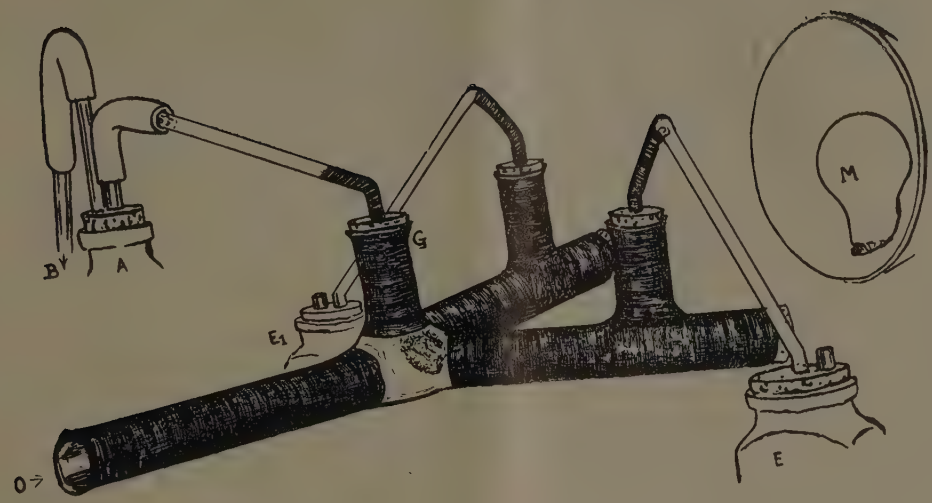

Fig. 1. General arrangement of olfactometer showing shape of Y tube and extent of wrappings. The support, the box over the fork, and the covering cloth are not shown.

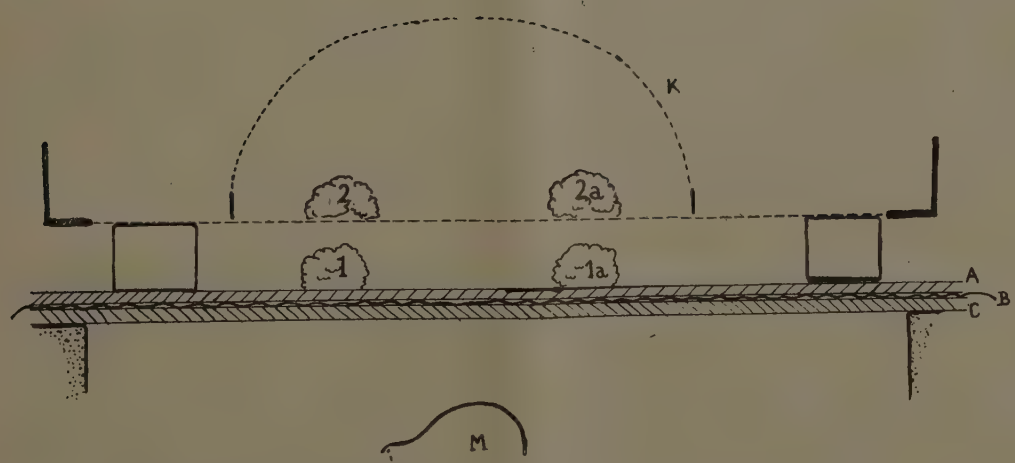

Fig. 2. Showing general design of the cage olfactometer, the covering cloth is omitted.

Olfactometric Experiments.

To provide data by which the second hypothesis could be examined, recourse was made to a series of olfactometric experiments in which adult froghoppers were exposed to various odours, and their responses noted.

Apparatus and Methods.

Two types of apparatus were used, the first being an olfactometer modified from the pattern designed by McIndoo (3), the second a simple apparatus of the writer's own design. The general design of the McIndoo olfactometer can be appreciated from the diagram (Fig. 1). Briefly, water is siphoned from flask A to B, and air is drawn through the symmetrical arms of a Y tube, and if previously drawn over odoriferous substances carries them down in each arm. An insect enters the Y tube at O, and moves under the influence of a centrally placed light at M towards the forks, where it is confronted with alternative odours. As other factors are equal or compensating, it is expected that in a number of tests, a larger total of insects will be taken from the arm down which travels the more attractive odour.

As the results from this apparatus could in many circumstances be legitimately questioned, it is absolutely necessary to state in detail the objections which have been noted, and the methods of circumventing them adopted in the present investigation, and to indicate the causes of variation between individual results. The principal objection is that conditions inside such apparatus do not reproduce conditions in the field. The optical and olfactory stimuli offered are at least a reasonable parallel to similar stimuli in the field: the nature of the surface traversed, the restriction of motion to a walk, and the degree of crowding are abnormal. These points were taken into consideration. It was found that froghoppers were able to move freely on the Pyrex glass which was used, and they did not drop when walking along the upper side of the tube. Before they were allowed to enter the olfactometer, they were kept for a quarter of an hour in a tube of slightly smaller diameter after having been collected in a field within a few hundred yards of the laboratory, and transferred to a moist cage. A few stunned themselves by impact with the glass when attempting to leap in the tube. Such insects were removed and either rejected or were used later when they showed a ready phototropic response and moved without sign of injury. The somewhat slow shuffling walk adopted by *Tomaspis* was well suited to the experiment, as it increased the likelihood of the insect entering slowly the area in which it encountered both odours simultaneously. To reduce any effect due to overcrowding, not more than thirty insects were used in a single run, while the inside diameter of all the tubes traversed by them was uniformly 1⅛ inches.

Consideration of Competing Influences.

McIndoo recorded that some insects were turned accidentally into the arms of the Y tube simply as a result of striking their heads against the curved glass in front of them before they had oriented themselves towards the odour preferred. If the apparatus were truly symmetrical, the number of insects passing into each arm from this cause would ultimately be equal in replicated experiments. A more serious objection, noted by the same writer, is that many insects passed through the fork of the tube too quickly, not having time to be oriented by the odours. It is by no means unlikely that the presence of a strong stimulus, such as light, inhibits response to a weaker stimulus, such as odour. It has, moreover, been shown that an insect, when subjected to two stimuli, responds to one, and does not take up an intermediate position (4). The stimuli affecting insects inside an olfactometer, other than aroma, are (*a*) light, (*b*) temperature, (*c*) humidity, (*d*) air movement, (*e*) sex: it was necessary that all these be adjusted on a compensating basis or eliminated, and the following measures were adopted.

(*a*) *Reduction of Light Stimulus.*

The continuous use of a single light suspended midway between the two forks of the Y was considered unsatisfactory for the following reasons: (i) The primary and possibly total response of the insects with such an arrangement is phototropic, and a very large number of replications of each experiment would be needed to enable differences due to response to odours to be discerned. (ii) The light, as seen through the slight ripples in the glass when viewed through the entrance tube (O), was distributed in a series of arcs, not absolutely symmetrical on each side. (iii) In preliminary trials of the apparatus it was found that the insect on approaching the fork, where an irrevocable choice between odours was expected, showed no decrease in the speed of its advance.

It was accordingly decided that the light stimulus should be used only to bring the insects to the 'threshold' or area just before the fork, and then should be removed. With this in view, the whole instrument, apart from the fork itself, was covered on the outside with layers of gummed red paper, so that no light could enter except at the fork. Care was taken to preserve the symmetry of area exposed at the mouth of each tube. A box, as used by McIndoo, was placed over the whole of the central portion to eliminate all sidelights. The light was supplied by a 60 watt bulb with reflector situated between, and eight inches beyond, the end of the symmetrical arms. A curved piece of grease proof paper placed between the base of the arms served as a diffusion screen, providing evenly dispersed illumination when observed through the entrance tube. To avoid extraneous light entering by other sources, the glass tubes bringing the odours

were darkened near the point where they entered their respective corks in the olfactometer. When the light was switched off a black cloth was dropped over the olfactometer, making all completely dark within.

(*b*) *Temperature.*

A record was kept of the external temperature while making the experiments and the temperature in the tubes was measured between tests. It was found that during the hours of the day when the experiments were carried out temperatures varied between 78° and 84°F., and that those inside the tube remained the same as outside.

(*c*) *Humidity.*

The relative humidity outside was at all times high during the experiments. An attempt was made to keep it as near saturation as possible inside the apparatus, and water was maintained at equal levels in the bottles containing the odoriferous substance. A test was made to determine the response of *Tomaspis* to a strong current of moist, as opposed to one of drier air. One of the bottles was filled with water to within ⅛ inch of the end of the tube leading to the olfactometer, while the other bottle was filled with calcium chloride, and a long glass tube was inserted to carry the air drawn into this bottle to the bottom whence it would be drawn over the calcium chloride. Humidity readings taken close to the point of exit gave 95 per cent. for the moist air and 78 per cent. for the dry. (*See* Table I, No. 1.) The contrast between the degrees of moisture was slight, but both chemical dehumidifiers and low temperature drying could be held as likely to introduce competing factors (such as odour, or cold).

It was found that in the later tests the choice of moist air was more definite though not significant. This was very probably due to the insects which were used in the later tests having been kept without food and at a temperature in which their water loss would be fairly considerable. Froghoppers awaiting use were subsequently kept in a very moist chamber, but one in which they could not imbibe moisture.

(*d*) *Air Movement.*

The rate at which the excurrent stream of water was adjusted resulted in a very slow air current passing from the odoriferous substances down the arms of the tube. In 20 minutes two gallons of water were siphoned off. Every attempt was made to ensure that the resistance to air drawn over the odoriferous substances should be as nearly equal as possible in both arms. Wide mouthed bottles of identical size were used to hold the odoriferous substances (Fig. 1, E, E1.) They were filled with liquid to the same height, or packed with solids as evenly as possible. Tubes of identical diameter and length, and of practically identical curvature, led from these to the arms of the olfactometer. At the same time it was desirable to ascertain whether marked differences in the rate of air movement through the arms of the olfactometer would result in a significant choice of one side by the insects. The experiments on this point were among the first and the last to be carried out. On one side, air was led over water through two bottles, connected with a deeply looped tube of ¼ inch diameter; on the other, a normal bottle half full of water, with inlet and outlet tubes of ⅜ inch diameter, was used. The rate of siphoning was adjusted to remove the two gallons in slightly less than 15 minutes. (Table I, 2, 2A.) There is no indication of preference for one or the other air current. Both experiments, however, in spite of replication, can only be accepted as evidence of the absence of an avid (as opposed to a slight) anemotropism. In the first experiment, there is reason to believe that the result shows primarily merely a phototropic response. In the second, the 32 per cent. which failed to leave the entrance tube, and the 17 per cent. which travelled up the air outlet tube (*i.e. with* the air current and not against it) indicated that the stimulus to movement offered by the air current was very feeble. The results showed that any slight difference in the speed of the alternative air currents in subsequent tests would be very unlikely to affect the validity of the experiment.

(*e*) *Interference of Sexual Stimulus.*

The insect material for the experiment was selected in the field, and, as is usual in populations of 'wild' specimens, mating had probably already occurred before the insects were captured. At the outset observations were made of the percentage mating in the cage where the insects were kept prior to use, and on their behaviour when relatively crowded in the olfactometer (before the glass was covered). It was found that in 10 tests an average of 3.8 per cent. mated when in the olfactometer, the highest percentage being 5. In the cage the daily average was 3.1 per cent., observations being made at irregular intervals. There is thus reason to consider this stimulus as of negligible importance when interpreting results.

It was hoped that by the reduction or elimination of competing 'major' stimuli (*i.e.* stimuli most closely governing the sustenance of the insect), response to aroma would become marked. It was realized that an adequate pause at the fork was necessary for orientation to take place, and with the apparatus as modified this occurred to a satisfactory degree. The insects were observed on a few occasions through clear glass affixed across the entrance to the olfactometer (the cloth in this case being lifted for a few moments), and could be seen revolving slowly on the threshold, sometimes pausing and waving their protarsi in the air. Moreover, it was found that the insects frequently ended their journey congregated around the thin

tube along which the aroma was brought through the cork into the olfactometer. Sometimes this happened in both tubes at once, and can reasonably be regarded as proof of an olfactory response. Others congregated inside the outlet tube, where they were exposed to a mixture of both odours. Although it has no bearing on the positive or negative choice of a given odour, their presence in the outlet tube is a confirmatory sign of interest on the part of the insect in the odours proferred, and serves to indicate that in seeking the inlet tubes the insects were tracing the aroma, and not following an accidental humidity gradient.

In conducting the experiments further precautions were found necessary. Firstly, at an external temperature of around 80°F. it was found that the odour of cut canes and, more particularly, of cane extracts, changed sufficiently markedly within two or three hours to be noticeable to the experimenter. Consequently, fresh supplies of cane were used for each experiment, while extracts were made afresh after every two experiments. A further difficulty was the elimination of residual or 'clinging' odour. All the glass was washed and cleaned with separate pieces of wet followed by dry cloth; (the wet cloths were not used twice on the same day, and were washed after use); while in the absence of a sufficient supply of tightly fitting corks, a thin slice was cut from the bottom of each cork with a razor after each test. The residual aroma was often easily detectable on such slices.

Notwithstanding these precautions, there still remained two sources of experimental error, which prevented the discovery of all but the most obvious differences in response in experiments of the somewhat low number of replications which have so far been made. The first source is the torpor which falls on most insects when in the dark. It may be that in darkness there is a tendency for thigmotropism to become appreciable. The number of insects which failed to move from the threshold when the apparatus was darkened is given under the heading "Per cent. total not participating". The second source of experimental error is due to an apparently fortuitous wandering on the part of some insects, as a result of which they may enter one of the arms of the olfactometer without having responded to the odour which is drawn through it. The meanderings of such insects tend to balance out as selection of the arms is at random, but it is one of the factors which make necessary at least a moderate degree of replication.

This is well shown where cut portions of a leaf of B. 3013 with water were compared with a control of air passed over water (Table I, No. 3).

Results of Experiments.

The explanation of the fact that more insects travelled towards the moist air (with no perceptible aroma) in preference to the moist air with an aroma of sugar cane in the outlet tube, (Fig. 1, G) is that the great majority walked along the bottom of the horizontal tube, and were thus liable to reach and pass the fork without becoming oriented towards the mouth of the outlet tube immediately above their heads.

The experiments were begun with a comparison of responses to BH. 10(12) and to Guatemala Grass. The grass and the cane, both mature in development, were cut into 4-inch lengths, and were packed on end into the bottles with approximately equal closeness. The number of lengths of each used to obtain this packing was nearly identical. Half an inch of distilled water of normal temperature was maintained in the bottom of the jars. This general arrangement was used in all tests of cane leaf. The results showed a significant preference for the odour from the leaf of BH. 10(12) (Table I, No. 4).

Next, BH. 10(12) was compared with *Saccharum ciliare*, and again a significant difference was noted in favour of the aroma from the cane (Table I, No. 5). Then the commercial variety Co. 213 was compared with BH. 10(12), in a higher number of replications (12) and a difference was noted in favour of the latter (Table I, No. 6). These results are in conformity with evidence obtained in the field. A series of experiments was next carried out in which cut leaf material of BH. 10(12) was compared with an extract made of one leaf of the same variety macerated and extracted with 200 cc. water at 70°F. The extract was filtered twice through a filter paper (No. 1) or twice through a linen cloth doubled (No. 2). The result showed no significant difference (Table I, No. 7, 7A). In view of this result it was considered legitimate to test both cut cane leaf and an extract made from such a leaf against a two per cent. solution of Trinidad No. 1 sugar, once filtered. Cut leaf material of B. 3013 and of BH. 10(12) was compared with this solution, and an extract of BH. 10(12) was also compared with it. In the experiments with cut leaf material, no significant differences were obtained in the number of replications made, (Table I, No. 8, 8A), and a similar result was obtained with the leaf extract (Table I, No. 9).

As a check on the working of the olfactometer a test of a three per cent. sucrose solution *versus* water was made, and gave a significant response in favour of the sucrose (Table I, No. 11). These findings were of interest, as a refractometer test of a typical sample of leaf extract No. 1 (kindly made by the Department of Sugar Technology) showed that the amount of sugar present was negligible. Thus odoriferous components of the leaf other than sucrose and sucrose in two per cent. and three per cent. solution proved equally attractive to froghoppers.

Table I.

No. of Expt.	Time of Exposure at each test in mins.	No. of tests.	No. of insects per test.	% Total insects attracted to :—		% total not participating.	% total in upper outlet tube.	Significance of difference.	Notes.
1	20	8	30	moist air 54.1	dry air 25.9	15	5	not significant	
2	15	6	25	Air current slow 42	fast 48	6.7	3.3	not significant	With light continuously
2A	15	4	25	28	23	32	17	not significant	In darkness
3	20	8	25	B.3013 leaf 72	moist air 11	12	5	significant	
4	20	10	25	BH. 10(12) leaf 65	Guatemala grass 20	15	0	significant	In darkness
5	20	8	25	BH. 10(12) leaf 68.5	Sacc. ciliare 7.5	21	3	significant	In darkness
6	20	12	25	BH. 10(12) leaf 55.3	Co. 213 28.3	10.6	5.6	significant	In darkness
7	20	10	25	BH. 10(12) Extract No. 1 42.4	leaf 54.8	2.8	0	not significant	In darkness
7A	20	8	25	BH. 10(12) Extract No. 2 46.5	leaf 30	20	3.5	not significant	In darkness
8	20	6	25	BH. 10(12) leaf 39.3	2 % sucrose 27.3	24	9.3	not significant	In darkness
8A	20	8	25	B. 3013 leaf 34	2 % sucrose 48	16	2	not significant	In darkness
9	20	6	25	BH. 10(12) Extract No. 2 42	2 % sucrose 33.3	24	0.6	not significant	In darkness
10	20	6	25	BH. 10(12) Extract No. 2 78	water 12	6	4	significant	In darkness
11	20	7	25	3 % sucrose 68.4	water 19	8.6	4	significant	In darkness
12	20	10	25	BH. 10(12) Extract No. 2 65.6	Extract + 3 % sucrose 18.8	13.6	2	significant	In darkness

Table II.

No. of expt.	Time of exposure in mins.	No. of tests.	No. of insects per test.	% of total no. insects attracted to :—		% total insects not participating.	Significance of difference.
1	15	6	40	BH. 10(12) Extract No. 2 81.7	water 12.9	5.4	significan-
2	15	10	40	BH. 10(12) Extract No. 2 23.25	Extract + 3 % sucrose 76	0.75	significant
3	15	10	40	B. 3013 Extract No. 2 24.75	Extract + 3 % sucrose 71.25	4.0	significant
4	15	10	40	B. 3013 Extract No. 2 84	water 14.75	1.25	significant
5	15	10	40	3 % sucrose 70.25	water 27.75	2.0	significant

At this point a second olfactometer of different design was brought into use. Its design is shown in Fig. 2. In it, liquid odoriferous substances in equal sized wads of cotton wool (1, 1A) were placed on a glass plate (A), below which was a diffusion screen of paper (B), and a further glass sheet (C), the whole being illuminated by a 60 watt pearl bulb from below (M), with an air current passing over it to avoid heating. A gauze cage (K), flat at the bottom, was suspended ⅛ inch above the odoriferous substances and was darkened above and on all sides by means of a cloth. Insects were inserted into the apparatus through the top. The advantages of this apparatus were that it avoided all crowding, and the light stimulus to move could only be obeyed by moving anywhere in a plane at right angles to the direction of the light. Thus grouping might be expected to occur near the sources of odour and moisture. Unfortunately, although grouping occurred above the baits, subsequent dispersal occurred—a general bustling to and fro—while a large proportion of insects did not participate. It was then decided to substitute tangible instead of remote baits, to encourage an insect to stay when it had reached its objective, and accordingly, in subsequent trials the soaked pads of cotton wool was placed inside the cage, on its floor, directly above four equidistant and evenly illuminated marks on the glass below (2, 2A). This arrangement worked very satisfactorily, in that over 90 per cent. of the insects participated and made a choice. It could no longer be regarded as an olfactometer, however, as means were available for insects to make their choice by actual imbibition and taste of juices. There were two criteria by which the extent of primary selection by taste, as opposed of olfaction, could be judged: (i) by independent tests of the solutions on the modified McIndoo apparatus; and (ii) by observation of the behaviour of froghoppers when released in the cage. If sampling by taste had been the basis of choice, then a preliminary grouping of approximately even numbers (in replicated tests) on each lure within two or three minutes would have been expected, followed by a migration to the more attractive juice.

The observations of froghoppers in the cage showed that no appreciable migration from one wad to another took place: once a froghopper had settled, it usually remained on the wad, and accordingly the differences recorded in the numbers visiting different pairs of wads was the result of a primary selection without imbibition.

Attempts were made to discover what froghoppers would do if transferred from the wad which they had selected on to another (the only source of light being kept constantly below the baits). Individuals were gently and swiftly transferred with tweezers. Many, on being released on the new wad, leapt away or took to flight without pausing; others, however, after resting immobile for several moments, began to feed on the new substratum (only 'acceptable' substrata were used in this experiment: no repellant fluid was employed). This behaviour could be partially explained by supposing the immediate need of the insects chosen to be *moisture*, irrespective of desirable solutes. This is somewhat unlikely as the insects had been maintained in a moist atmosphere for over an hour before being transposed. It is also possible that their behaviour was the result of a 'prolonged reaction', in which the initial response to the stimulus to feed was maintained although the strength of the stimulus was increased or decreased, according to the direction of the transposal.

The experiments were resumed with a test of leaf extract BH. 10(12) *v.* water in both olfactometers. A significant result in favour of the extract was obtained in both (Table I, No. 10; Table II, No. 1). Tests in the 'cage' with extract of B. 3013 leaf *v.* water also gave a significant result in favour of the leaf extract (Table II, No. 4). These results, together with a similar result of a three per cent. sucrose solution *v.* water (Table II, No. 5), indicate that the need for moisture was not 'swamping' the selection by odour in the 'cage'.

The final tests compared the attractiveness of leaf extract of BH. 10(12)—No. 2 type—with such leaf extract+three per cent. sucrose in 2 : 1 proportion, and of leaf extract of B. 3013 *v.* the same extract+three per cent. sucrose (2 : 1). The results showed a significant preference for the leaf extract+sucrose for both varieties of cane. (Table I, No. 12; Table II, Nos. 2 and 3).

Summary of Results.

In field experiments, it has been shown that Co. 213 and Uba were less attacked by froghoppers than other varieties including BH. 10(12), a normally 'susceptible' variety under plantation conditions. No differences in leaf structure were found which would support the theory of mechanical protection of Co. 213 against attack. In olfactometric tests the difference in selection by froghoppers was found to be the same as noted in the field; it was also found that the odour of a leaf of BH. 10(12) was preferred to that of a grass (Guatemala grass) and of a non-commercial cane *Saccharum ciliare.* The explanation of the 'resistance' of Co. 213 and Uba which at once offers itself is that froghoppers, when able to obtain a choice, largely attack the canes with the most attractive odour, though quite well able to feed on any variety at need. Such an explanation would fit in with the observations (i) that all canes now commercially grown in Trinidad may suffer from attack, (ii) that on the whole noble canes suffer more than those with a large proportion of wild blood.

Concerning the nature of the attractant, it was noted that odours from a leaf-extract were no more attractive than odours from a leaf; that leaf extracts practically devoid of sugar were as attractive as a two per cent. solution of sucrose; and that leaf extract with three per cent. sucrose (2 : 1) was definitely preferred to leaf extract alone. Both the sucrose and the leaf extracts were preferred to water alone.

These results show that there are two attractants in the plant, both of which will occur in varying quantity in the leaf. To the experimenter the fresh leaf extract was strongly reminiscent in odour of newly-cut grass: the sucrose solution from No. 1 sugar had a faint aroma of molasses; that from refined sugar was odourless. The isolation of the substances responsible for the 'grassy' odour could not be undertaken in the time available. The point of greatest interest in the present investigation, however, is that sucrose, which is needed in high concentration in commercial cane, is itself an attractant to froghopper.

It seems unlikely that the 'grassy' odour of sugar-cane will be reduced by selection or breeding, though it is possible that it has its own grades of attractiveness: it is certainly undesirable that canes of low sucrose content should be grown. Moreover, absolute 'lack of attractiveness' arising from failure on the part of the sugar cane to stimulate froghoppers through their olfactory receptors is not known at present, and is not likely to be attained. Such lack of attraction is far more likely to result from the presence (within range of the olfactory receptors of the froghopper) of another variety comparatively more desirable. Indeed, there is some danger that the 'good' performance of a variety in randomised plot experiments on varietal resistance may result rather from the fact that it is surrounded by more attractive varieties than from any absolute relationship between its physiological characteristics and the responses of *Tomaspis.* It is very possible that such a variety in a large stand would fare no better as regards infestation than any of the comparatively resistant types now in use, if no more attractive types were available in the area.

The questions of intrinsic ability of varieties to tolerate attack, or to recover rapidly after attack, when exposed under conditions which equalize among all varieties the effect of water balance and of nutrient and physical status of the soil, have scarcely been touched, as their investigation depends upon a heavy blighting of the experimental plots, and such blighting has not yet occurred.

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ENTOMOLOGICAL NOTES.

(Compiled by the College Department of Entomology.)

Insect Pests in Jamaica.

Mr. W. H. Edwards reports that during 1937 sugar-cane in Jamaica was attacked by *Aphis sacchari* Zehnt. in one district, after heavy and prolonged rains in October, and by *Lachnosterna* and *Metamasius sericeus* Ol., in other areas. Continued observations on the comparative incidence of *Diatraea saccharalis* F., on varieties of cane showed that nodal infestation was highest (10.89 per cent.) in F.C. 916.

In order to establish the predator, *Plaesius javanus* Er., which was imported from Fiji for the control of *Cosmopolites sordidus* Germ. on banana, suckers were collected in areas free from Panama disease and planted closely in a severely infested field, in which the adult predators were later liberated.

Citrus was severely damaged in some districts by *Prepodes vittatus* L. and *P. similis* Dru. var. *amabilis* Waterh. Field counts showed that 25 per cent. of the eggs, which occur in batches of 60 to 100 between pairs of leaves, were parasitised by *Tetrastichus haitiensis* Gah. This Eulophid can easily be bred from egg-masses of *Prepodes* collected in the groves, and constitutes an easy additional method of control. Newly hatched larvae of *Prepodes* were attacked by ants, and older ones by the predaceous larvae of *Pyrophorus luminosus* Ill.

Dusting with sodium fluosilicate gave effective control of *Herse cingulata* F., *Chirida signifera* Hbst., and *Metriona flavolineata* Latr. on sweet potato, whereas dusting with calcium chloroacetate injured the foliage. Larvae of *Ligyrus tumulosus* Burm. and *Lachnosterna jamaicensis* Arr. infested the roots and *Chlorida festiva* L. and *Estola attenuata* Fisher the stems of egg-plant (*Solanum melongena*), which was also attacked by *Epitrix parvula* F. and *Solenopsis geminata* F. *Corythuca gossypii* F. caused severe injury to *Cajanus indicus*, and it was also common on egg-plant and *Hibiscus* spp. Other injurious insects recorded include *Apate monacha* F., *Asterolecanium palmae* Ckll. and *Xyleborus perforans* Woll. on coconut, *Plutella maculipennis* Curt. (*cruciferarum* Zell.) on cabbage and *Phthia picta* Dru. on tomato. A consignment of 700 adults of *Dasyscapus parvipennis* Gah. was received from Trinidad in August for the control of *Selenothrips rubrocinctus* Giard, and the parasites were liberated on infested mango trees. They were recovered in small numbers at the end of the year, but it is not yet known whether this Eulophid will control the pest effectively under local conditions.

Destruction of timber by termites has increased considerably during recent years. The most harmful are *Calotermes* (*Cryptotermes*) *brevis* Wlk. which attacks dry wood, *Heterotermes* (*Leucotermes*) *tenuis* Hag. which lives in the ground, and *Eutermes* (*Nasutitermes*) *ripperti* Ramb. which forms its nests on trees or posts and attacks timber kept in conditions of moisture. The reasons for the increase of *Calotermes brevis* and *H. tenuis* include the scarcity of native hardwoods and the consequent use of imported soft woods, the lack of precautions to prevent the pest from reaching hidden recesses, and the large number of newly erected buildings which, being close together, encourage the spread of *C. brevis*. The large numbers of *E. ripperti* in the older urban districts are due to the rebuilding of wooden structures without the thorough clearing of old wood from the site, as well as to the use of susceptible timber instead of native hardwoods for buildings and for closely spaced fence posts. A list is given of wood-boring insects other than termites, that were observed during the investigations, showing the types of wood in which they were found. — (*Rev. Appl. Ent.*, A, Vol. XXVII, pp. 238-239, 1939.)

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Insect Pests in St. Vincent.

It is reported that infestation of arrowroot in 1937 by larvae of *Calpodes ethlius* Cram. was less severe than in 1936, but caused serious losses throughout the island in October. Very little control was given by parasites, owing to the dry weather. Artificial defoliation of plants to simulate the damage done by the larvae caused 18 to 38 per cent. reduction in the yield of rhizome, and some reduction in the average starch content of the crop. As control of this Hesperiid by dusting with Paris green has proved uneconomic, spraying with a commercial colloidal lead arsenate was tried, and one application of a suspension of 3 lb. in 100 gallons water gave effective control. The same spray was also effective later in the year against *Alabama argillacea* Hb., which was favoured by the dry weather and defoliated about 150 acres of cotton.

Preliminary investigations on the possibilities of control of *Platyedra gossypiella* Saund. on cotton showed that the most important causes of re-infestation were inter-island traffic, failure to uproot all cotton plants and an inadequate close season. Resting larvae in seed buried six to nine inches deep did not survive the close season.

Owing to the appreciable increase in incidence of *Diatraea saccharalis* F. and *D. canella* Hmps. on sugar cane, planters are advised to soak all cuttings in an aqueous suspension of lime before planting, to cut the canes as low as possible at harvest and avoid leaving canes in the field, and to pay particular attention to field sanitation.— (*Rev. Appl. Ent.*, A, Vol. XXVII, pp. 271-272, 1939.)

SUGAR NOTES.

(Compiled by the College Department of Sugar Technology.)

Blackstrap Molasses as Raw Material for Biochemical Industries (Plant Design Requirements).

This is another important article for the distillery technologist *, which should be studied in detail. It deals with: (i) the culture propagating system; (ii) the piping system for the direct flow of culture material to the fermenters; (iii) the choice of plant materials; and (iv) provision for temperature control. Here space can be found only for the more important of the author's points under these four headings.

(i) The standard type of pure culture system was originally designated for yeast propagation, where, owing to the protective acidity of the mash, the chances of contamination were naturally remote, but in other processes where the pH of the substrate is in the vicinity of 6.0, the dangers from infection are much greater.

In the latter cases much more attention has to be given to the valves and pipe lines where infection may build up and produce serious consequences. In these cases the standard pure culture system has to be modified to include streamline fittings, providing for the rapid dismounting and cleaning of pipes, valves, &c.

(ii) In all of the processes so far described it is necessary for the flow of the seed material to be as direct as can be devised. In some, notably that for ethyl alcohol, pockets in the lines may rarely be the occasion of trouble in fermentation, but in others it is imperative that the plant design provide, not only for a direct flow of seed material, but that pipe-lines should be more streamlined and easily removable.

(iii) Today, in the modern distillery, wooden fermenting tanks are no longer used, owing partly to the general practice of utilizing the gases. In metal fermenters considerable corrosion is liable to be caused. Hence they are constructed from various steel alloys, one of the most popular of which is copper-bearing steel with 0.20 to 0.25 per cent. of Cu. The effect of dissolved metals on the propagation of the yeast is well known, and recently the author observed a case of iron poisoning in an old plant. Only by giving the entire interior of the fermenter a treatment with caustic soda followed by thorough washing was it possible to obtain an efficient yield from the molasses mashes.

According to Weiner † the advantage of copper bearing steel is due to the fact that the copper tends to hold the oxidized iron on the surface of the steel, thus forming a film which is highly resistant to corrosion. Where copper-cooling coils are used in steel fermenters there is a possibility of electro-chemical action, which may sometimes be quite serious. Hence great attention must be paid to the choice of metals between which no such action may occur.

(iv) Usually in the modern distillery the fermenters are so large as to preclude the use of adequate cooling facilities in them, and dependence must be placed upon setting the mashes at a suitably low temperature so that it does not exceed 104°F.; sometimes the setting density of the mash is reduced. Seed tubs must always be provided with cooling coils. In the modern plant both fermenters and seed tubs are equipped with recording thermometers, and sometimes with recording hydrometers, and not infrequently also with recording potentiometers. —(*Inter. Sugar Journal*, Vol. XLI, No. 488, 1939, pp. 321-322.)

* For previous articles in this series *see I.S.J.*, 1937, pp. 190, 281, 405; 1938, pp. 118, 156, 441, 482; 1939, p. 35.

† *Chem. and Met.*, XLIV, pp. 710-714.

* * *

Utilization of Molasses (on Yeast and Lactic Acid Production).

Considerable time has been devoted to clarification experiments on suitable molasses. Eventually a cheap and satisfactory method was worked out, by which a molasses mash of 15 to 20° Brix, clear and free from sediment or cloudiness, can be prepared in large amounts in less than a day. This clarification process has been carried from laboratory methods to the stage of small pilot-plant methods, finally filtering the treated molasses through a laboratory model of the Oliver 'pre-coat' filter. By this method, clean yeast, free from contamination by molasses solids and easily separated from the molasses, can be prepared if desired. This kind of yeast may be used for human food, as a vitamin and protein supplement to diets which are sub-optimum in these respects. In the preparation of yeast for animal feeding, the preliminary clarification of the molasses has been omitted, since a satisfactory method has now been found for drying the yeast in a thick suspension, without filtering it. Hence, this procedure eliminates two filtrations, with a consequent marked decrease in the cost. Experiments at the Hawaii Agricultural Experiment Station will give information on the actual feeding value of the yeast manufactured by these methods, when fed to various classes of farm animals. Further studies have been carried on to determine the optimum conditions of growth for lactic acid bacteria on molasses media. The organism reported on last year, as being superior in lactic acid production to imported organisms, has shown an increasing tendency to grow vigorously in the higher concentrations of molasses, up to 25 per cent. It is also somewhat unusual in that it produces only dextro-lactic acid, which is completely assimilated by the animal body, whereas the laevo-acid is only very slowly assimilated.—(*Inter. Sugar Journal*, Vol. XLI, No. 488, 1939, p. 322.)

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Movement of Water in the Soil.

In his presidential address to the Royal Meteorological Society, B. A. Keen gave an account of how a theory of the movement of water in the soil that has long been generally accepted, and which provides a simple and plausible explanation of certain traditional cultivation practices such as rolling, harrowing and hoeing, has had to be abandoned in recent years and to be replaced by a new theory developed and experimentally verified mainly by Haines and Schofield (*Quart. J. Roy. Meteor. Soc.*, April, 1939). The old theory is the capillary theory of soil water movement, according to which the rain that percolates to some depth into the soil forms a reservoir that can be drawn on by plants in drought, the water ascending by capillary tubes, built up from the spaces between the soil particles, from saturated levels many feet below the surface to supply the roots of the plants at higher levels. According to this theory, harrowing and hoeing conserve moisture by destroying the top few inches of the capillary tubes and so checking evaporation from the surface, while rolling crops in spring reverses the process by diminishing the space between soil particles near the surface and so allowing the capillary tubes to bring water to the upper layers of the soil. It was found at Rothamsted from observations on the water level in cylinders closed at the bottom and filled with various soils, the top being kept free of weeds, that capillary rise actually does not exceed 3 or 4 feet even in such a drought as that of 1921. Haines showed, moreover, that the pore space in soil is essentially cellular, not capillary, and that with both increasing and decreasing moisture content the movement of water takes place through sudden changes corresponding with the abrupt emptying and filling of the cells. Schofield investigated the marked hysteresis in moisture content according as the soil is being moistened or dried. Under the new theory, it may be noted, the value of cultivation lies in the encouragement of soil crumb formation, while its control of soil moisture is confined to the removal of weeds that are competing for moisture and nutriment. —(*Nature*, Vol. 144, No. 3639, p. 210.)

* * *

New Uses for Cotton.

Cotton experts, who are on the verge of giving up attempts to dispose by purely economic means a growing cotton surplus, are looking for new uses for cotton as a solution of one of America's most serious agricultural problems.

Many suggestions have been made, but only two so far give any hope of absorbing significant amounts of cotton without at the same time striking hard at some other material produced in the United States. One of these is the addition of five per cent. of cotton to cheap wood pulp paper and of 15 per cent. to superior grades of paper which would not only improve the quality of paper but also cut down American imports of wood pulp, as well as slightly reduce the cutting of America's forests.

Another possibility for consuming cotton on a large scale is the use of a cheap cotton fabric base for secondary roads. Most of the side roads in U.S.A. are still unsurfaced, though miles of concrete highway give a contrary impression. The cotton fabric serves as a cheap reinforcement for the crushed stone dressings and bituminous materials widely used.

Neither of these suggestions is, however, capable of application this year on the scale required to reduce the surplus substantially. The difficulties are due partly to the rise of other cotton producing areas outside the United States and partly to the growth of synthetic fibres. In 1926 world rayon production represented only 400,000 bales of cotton, but in 1937, the synthetic fibre, which is made usually from wood pulp, represented 4,000,000 bales of cotton—11 per cent. of the 1937 cotton crop throughout the world and 15 per cent. of the 1938 crop.

Rayon will continue its phenomenal growth as long as it is superior to cotton for many purposes. Among the leaders in the manufacture of artificial fibres, incidentally, are precisely those countries which were among the largest customers for American cotton: Japan, Germany and Italy. A new fibre—nylon, a synthetic substitute for silk—may be expected not only to hit silk, but cotton as well.

It would require an incredible amount of clothes to dispose of the available cotton. About 683,000,000 shirts can be made from 1,000,000 bales of cotton—more than five shirts for every man, woman and child in the United States, according to an expert of the U.S. Department of Agriculture. And the government is currently keeping out of the market 11,391,000 bales—almost the amount of an entire year's crop. Finding methods of putting more cotton into textiles would, therefore, achieve little. Almost every pound of government cotton put into cloth would mean one pound less of currently grown cotton used.

It is even suggested now that the trend of decades of plant breeding—to produce more lint and less seed from a given cotton plant—be reversed and that efforts to produce more seed and less cotton be made instead. Not only would that serve to reduce the amount of cotton produced, but it would also increase the amount of a highly desirable commodity—cottonseed. The hundreds of products made from cotton seed and cottonseed oil have given the seed a larger market than growers have been able to fill.—(From *Science—Supplement*. 1939. Vol. 89, No. 2320.)

TREND OF THE MARKETS.

[The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices are spot, London.]

SUGAR:—Prices on the Home Market have ranged as follows (c.i.f. per cwt.):—

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
27th July	7	1½	10	9
3rd August	6	10½	10	3
10th August	6	9	10	4½
17th August	6	4½	10	1½
24th August	7	1½	10	9
31st August	6	11	10	9
7th September	6	11	10	9
14th September	6	11	10	3
(*15th September*, 1938)	5	6	9	4½

The market which had been comparatively quiet was, towards the end of August, once again entirely dominated by the political situation which caused a general advance mainly due to covering orders against sales of Raws to Refiners and a heavy demand for Refined.

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows:—

	Pence per lb.
26th July	8 5/16
2nd August	8 1/2
9th August	8 9/16
16th August	8 9/16
23rd August	8 5/8
30th August	8 3/4
6th September	8 3/4
13th September	10 1/8
(*14th September*, 1938)	7 15/16

During the month of August which represents the period under review the tone of the market remained firm. Considerable business was done in nearby rubbers. This was accompanied by a large fall in United Kingdom stocks accounted chiefly by shipments to the Continent, mostly to France and Germany. On 23rd August, however, the export of rubber was prohibited except under licence by the Board of Trade. Towards the end of August the market was carrying on normally but business was of necessity very restricted. American consumption for July was 43,880 tons, a slight but expected fall from the June figure.

* * *

LIME PRODUCTS.—*Lime Oil.*—The nominal value of Handpressed is 27*s.* 6*d.* to 30*s.* per lb. but there are no available stocks. Distilled is quietly steady at 11*s.* 6*d.* per lb. *Lime Juice.*—There is no demand for Concentrated and Raw is very quiet at 1*s.* 9*d.* to 2*s.* 3*d.* per gallon.—(*West India Committee Circular*, 24th August, 1939.)

COCOA.—During the latter part of August the European political situation dominated all markets with cocoa proving no exception. With the declaration of war cocoa prices in New York advanced considerably with trading greatly disturbed. Due to the scarcity of cocoa combined with the above factor prices have also advanced locally, Plantation being offered at $9.25 per fanega and Accra is quoted at 29*s.* 6*d.* for spot business.—(*By Courtesy of the Cocoa Planters' Association of Trinidad, Ltd.*)

* * *

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian F.G.F. Giza 7*
28th July	5.40	6.49
4th August	5.28	6.62
11th August	5.22	6.49
18th August	5.14	6.49
25th August	5.52	7.38
1st September	5.71	—
8th September	6.98	—
15th September	7.01	—
(*16th September*, 1938)	4.81	7.52

There were only minor fluctuations in raw cotton prices until towards the end of August when all other matters in trading circles were overshadowed by the political crisis. Prior to that period the first estimate of the American crop which was given at just under 11½ million bales had little effect on prices. As the crisis developed traders remained calm but the general opinion was that lower prices for raw cotton and manufactured goods were improbable. Prices in Liverpool in effect rose and there is at present a distinct upward tendency. West Indian Sea Island has been entirely neglected. English spinners have sufficient stocks and Continental spinners are not at present interested.

* * *

BANANAS.—The trade has been only fair in view of the quantity of seasonal home soft fruit on the market, such as plums and apples. Prices of Jamaicas are unchanged at £20 15*s.* delivered London, and £20 10*s.* delivered nearest station Provinces. Demand for Brazilians was poor and values are quoted at £15 nearest station Provinces and £14 delivered London.

* * *

COPRA.—The market is dull but the value of September shipment f.m.s. is quoted slightly higher at £10 5*s.* 0*d.*